TITLE: Assessing the Hydrodynamic Performance of Fouling-Release Surfaces
(ONR Research Contract # N00014-07-WR-2-0213)

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BACKGROUND: The primary purpose of a ship antifouling system is to limit the increase in drag that will be incurred with fouling settlement on the hull. Ineffectiveness in this endeavor will lead to an increase in energy consumption and a platform that is unable to meet its mission. Non-toxic, fouling-release coating systems have been introduced as alternatives to traditional biocide-based antifoulings. However, for these systems to serve as viable alternatives to traditional biocide-based systems, their hydrodynamic performance must compare favorably with traditional systems over the entire coating life cycle. At present, few data are available to make these fundamental comparisons.

OBJECTIVE: The technical objectives of this research are to:

- Develop effective, generic roughness scaling parameters for a continuum of hull conditions.
- Implement this scaling to predict performance penalties of U.S. Navy ships.
- Collaborate with NSWCCD to incorporate these predictions with fleet operational data to perform a rigorous economic analysis of the cost of hull roughness and fouling to the Navy.

METHOD AND RESULTS: The technical approach of this research is to (see Figure 1 below):

- Develop roughness scaling parameters for a range of hull conditions based on hydrodynamic experiments by the PI (*i.e.* Schultz (2004)).
- Employ boundary layer similarity analysis to determine the increase in frictional drag at ship scale.
- Predict powering and speed penalties for the *Oliver Hazard Perry*-class frigate (*FFG*-7) and the *Arleigh Burke*-class destroyer (*DDG*-51) Naval surface combatants using model test data and frictional drag predictions.
- Collaborate with NSWCCD to carry out a rigorous cost/benefit analysis for hull roughness and fouling for the U.S. Navy combining the aforementioned powering predictions with data for ship operational profiles from the fleet.

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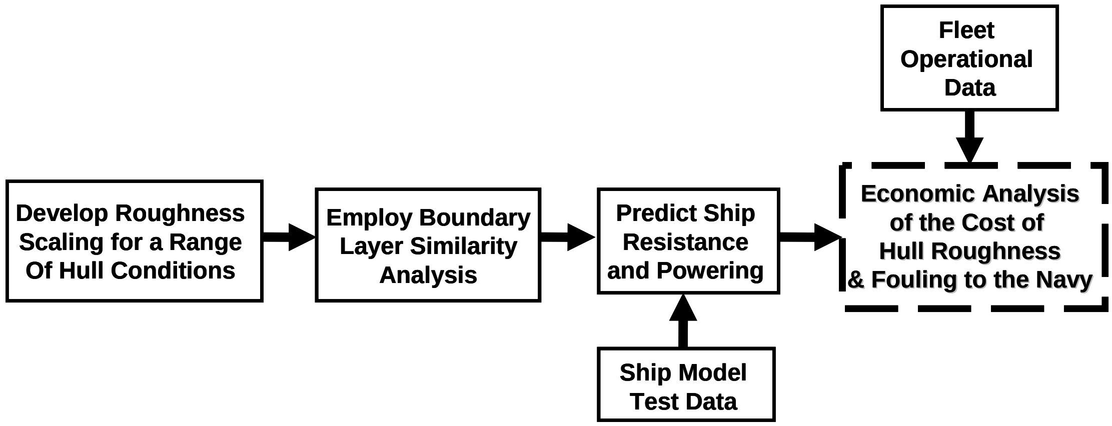

Figure 1 – Flow chart illustrating the technical approach employed the present research.

The following progress has been made in the 2007 fiscal year:

- Generic roughness and fouling scaling parameters have been developed for a range of hull conditions (Table 1).
- Predictions of the increase in total drag at cruising speed and near top end have been made for the *Oliver Hazard Perry*-class frigate *FFG*-7 (Tables 2 & 3) and the *Arleigh Burke*-class destroyer *DDG*-51 (not shown).
- Estimates of powering and speed penalties have been carried out for the *Oliver Hazard Perry*-class frigate *FFG*-7 (Figures 2 & 3) and the *Arleigh Burke*-class destroyer *DDG*-51 (not shown).
- Comparisons with full-scale ship trials data in the literature indicate that the present predictions are reliable (Figures 4 & 5).
- Collaboration is currently underway with NSWCCD to carry out a rigorous cost/benefit analysis for hull roughness and fouling for the U.S. Navy using combining the aforementioned powering predictions with data for ship operational profiles from the fleet.

Table 1 – Roughness scaling parameters for a range of hull roughness and fouling conditions. Note that the NSTM rating is the Navy hull fouling rating based on the Naval Ships' Technical Manual (NSTM, 2002), k_s is the equivalent sand roughness height, and Rt_{50} is maximum peak-to-trough roughness height over a 50 mm transect.

Description of Condition	**NSTM Rating***	k_s **(μm)**	Rt_{50} **(μm)**
hydraulically smooth surface	0	0	0
typical as applied AF coating	0	30	150
deteriorated coating or light slime	10 - 20	100	300
heavy slime	30	300	600
small calcareous fouling or weed	40 - 60	1000	1000
medium calcareous fouling	70 - 80	3000	3000
heavy calcareous fouling	90 - 100	10000	10000

* NSTM (2002)

Table 2 – Increase in total drag for the *FFG*-7 class frigate at a cruising speed of 15 kts (7.7 ms^{-1}) for a range of hull roughness and fouling conditions.

Description of Condition	**ΔR_T @ U_s = 7.7ms^{-1} (kN)**	**% ΔR_T @ U_s = 7.7ms^{-1}**
hydraulically smooth surface	--	--
typical as applied AF coating	4.6	2%
deteriorated coating or light slime	23	11%
heavy slime	41	20%
small calcareous fouling or weed	69	34%
medium calcareous fouling	105	52%
heavy calcareous fouling	162	80%

Table 3 – Increase in total drag for the *FFG*-7 class frigate at a speed of 30 kts (15.4 ms^{-1}) for a range of hull roughness and fouling conditions.

Description of Condition	**ΔR_T @ U_s = 15.4ms^{-1} (kN)**	**% ΔR_T @ U_s = 15.4ms^{-1}**
hydraulically smooth surface	--	--
typical as applied AF coating	46	4%
deteriorated coating or light slime	118	10%
heavy slime	192	16%
small calcareous fouling or weed	305	25%
medium calcareous fouling	447	36%
heavy calcareous fouling	677	55%

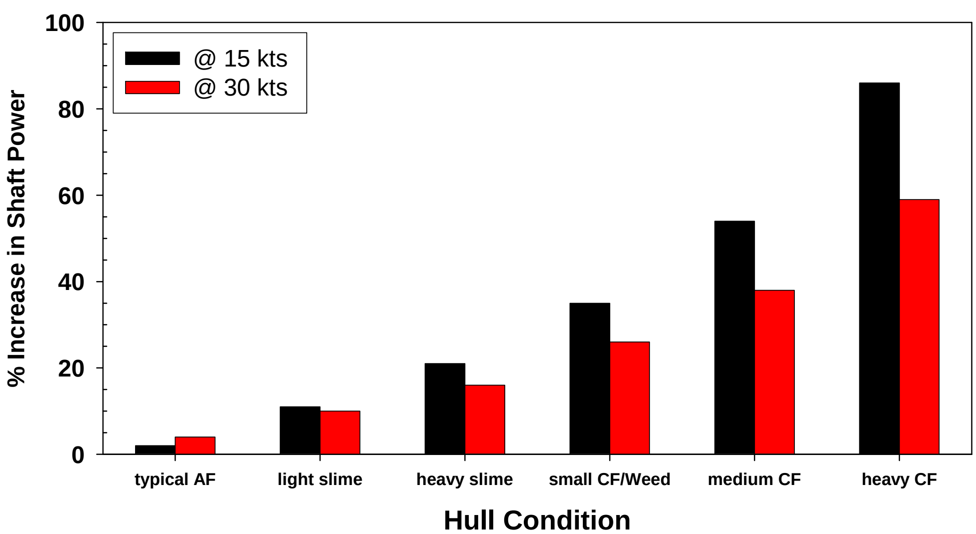

Figure 2 – Increase in required shaft power for the *FFG*-7 class frigate at 15 and 30 kts (7.7 and 15.4 ms^{-1}) for a range of hull roughness and fouling conditions.

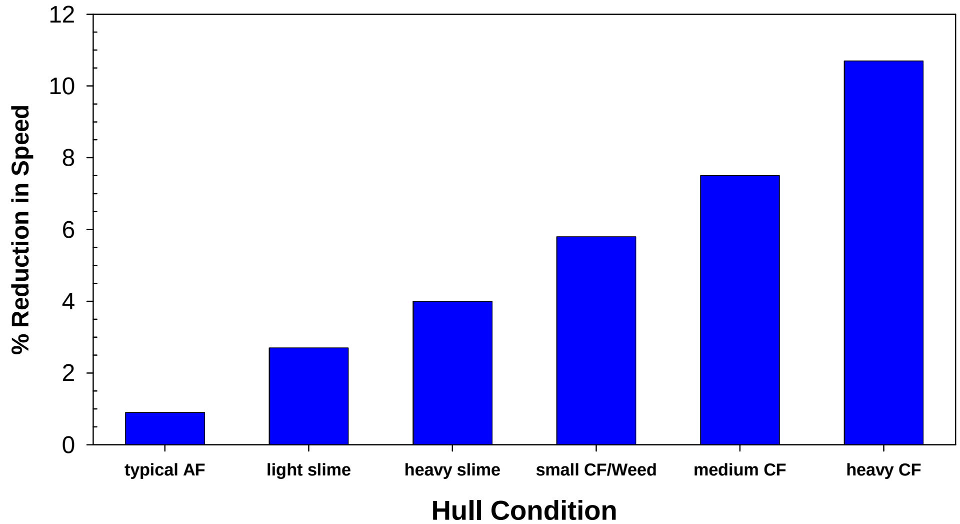

Figure 3 – Reduction in top end speed for the *FFG*-7 class frigate at a fixed input power corresponding to that required at 30 kts for a hydraulically smooth hull.

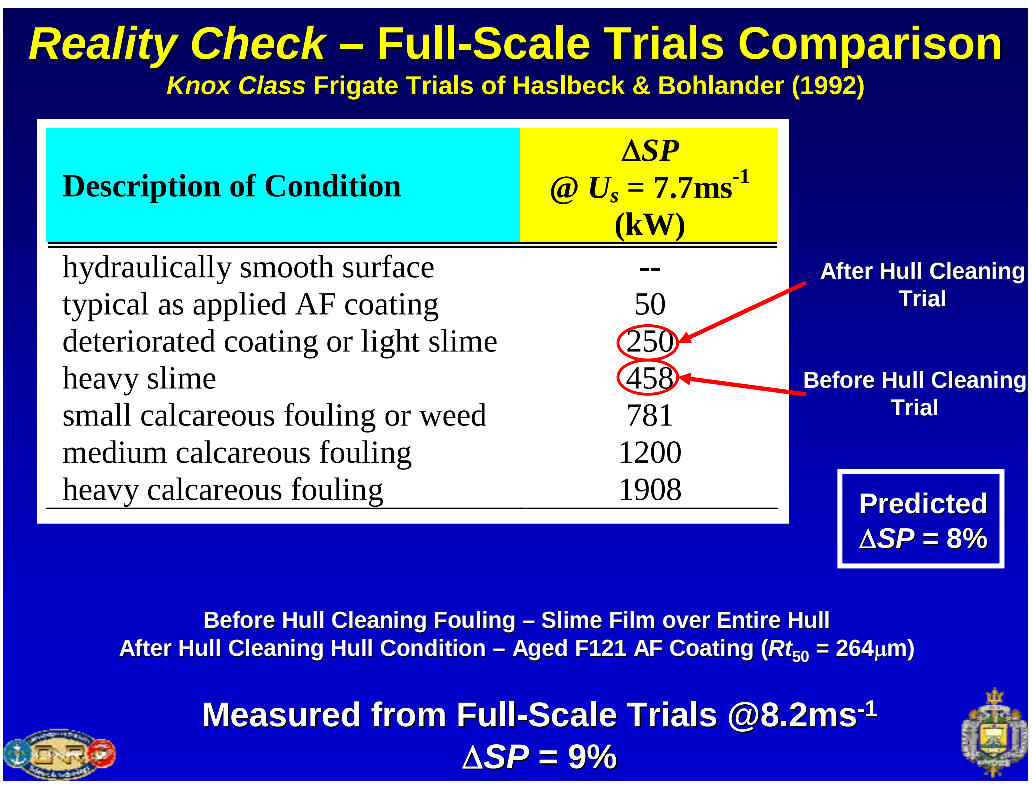

Figure 4 – Comparison of the present predictions to the results of Haslbeck & Bohlander (1992).

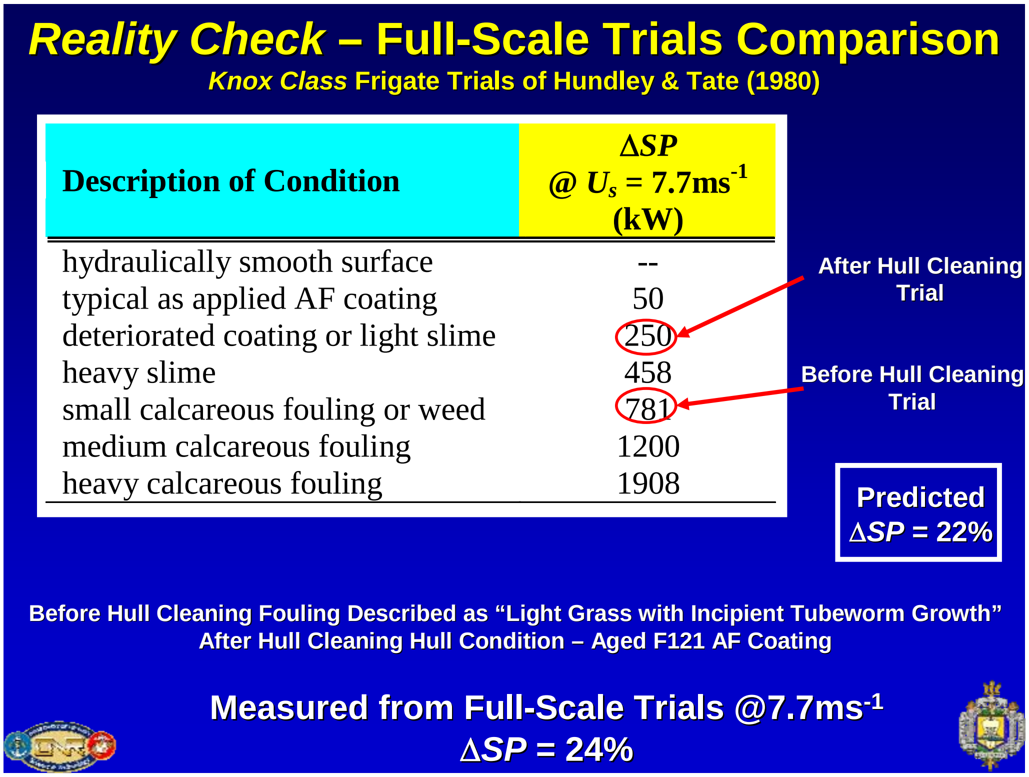

Figure 5 – Comparison of the present predictions to the results of Hundley & Tate (1980).

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